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Maine Potato Diseases, Insects, and Injuries

DONALD FOLSOM, G. W. SIMPSON, AND REINER BONDE

Identifying and roguing diseased plants are necessary for the production of good seed.

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BULLETIN 469

MAINE POTATO DISEASES, INSECTS, AND INJURIES

DONALD FOLSOM,[1] G. W. SIMPSON,[2] and REINER BONDE[3]

INTRODUCTION

This bulletin is intended to help farmers, inspectors, and students learn the names, causes, effects, and means of control of the various diseases and injuries found on potato vines and tubers in Maine. Any disorder of potatoes not described here should be referred immediately to qualified specialists, because there are a number of dangerous diseases and pests waiting to be introduced into Maine, and the sooner one of them is discovered, if present, the sooner it can be fought with a chance to eradicate it. More detailed information on many of the diseases and injuries briefly described here can be obtained from the publications listed at the end of this bulletin or from the Maine Agricultural Extension Service.

SOME TERMS AND THEIR MEANING AS THEY ARE USED IN THIS BULLETIN

Bacterium: (plural is bacteria) a "germ" or very small kind of living organism that lacks green color and therefore must live at the expense of the potato plant or on materials originally produced by the potato plant.

Blight: a disease that usually kills the vines, often rapidly.

Control measures: ways and means of reducing or eliminating disease or other injuries; some may be effective but not justifiable under the prevailing conditions.

Curling: bending down of the tip of a leaflet.

Disease: a disorder caused by a fungus, bacterium, or virus.

Disinfection: applying chemicals or heat to seed tubers, cut seed, storage walls, racks, soil, etc., to destroy or inactivate causes of disease.

Epidemic: a rapidly spreading or widely prevalent attack on potato fields or plants by a disease.

Fungicide: a chemical that helps to control a bacterial or fungus

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disease when applied to any part of the plant or to whatever might infect any part of the plant with bacteria or fungi.

Fungus: (plural is fungi) a very simple kind of plant that lacks green color and therefore must live at the expense of the potato plant. Familiar examples are the white mold in a tuber rot or around a late blight lesion, and the black scurf of the Rhizoctonia fungus.

Herbicide: a chemical that kills potato plants or weeds when applied to them.

Hill: the plant or plants growing from one seed piece.

Insect: an animal of the class Hexapoda, with six legs in the adult stage.

Insect adult: the final stage in the development of an insect—the stage that produces eggs or young.

Insect larva: the young stage of certain kinds of insects—often called maggots or worms.

Insecticide: a material that reduces insect injury by killing insects, repelling them, or otherwise curtailing their activities.

Leaf: the part of the potato plant that grows from the side of a green stem and that consists of a leaf stem, leaf axis, and leaflets (usually three to seven large ones and more small ones).

Leaflet: a thin, flat part of the compound leaf—a part that grows from the side or end of the leaf axis.

Leaf ribs: the main veins or supporting parts of leaf blades—parts which also contain passageways for soil solutions and food solutions.

Lesion: a single apparently dead or dying portion of some part of the plant. A large lesion or a combination of lesions may be called a rot, or may resemble burning (in leaves).

Mottling: light green or yellow spotting of the leaf blade.

Necrosis: premature death of plant substance with darkening of the affected portions.

Nymph: the young stage of certain kinds of insects, usually with legs and general form like that of the adult.

Plant: one main shoot or vine consisting of stem, branches, and leaves, with the attached roots, stolons and tubers.

Resistant: of such a nature as to be less subject to disease or insect attacks than most other plants or varieties.

Rolling: rolling up of the sides of a leaflet.

Rotation: planting other kinds of crops than potatoes so that the soil-inhabiting cause of a disease or insect injury may die out.

Russeting: a roughening of the tuber skin due to thickening, the outer layer of which has been broken into many small patches by continued growth of the tuber.

Rust: with scientists, a disease caused by a certain kind of fungus; with potato growers, any of several diseases and injuries that cause brown discoloration of the leaves.

Sanitation: cleaning up and destroying all remains of diseased plants in order to eliminate persistent sources of disease.

Seed: tubers or parts of tubers used for propagation.

Seed plots: fields planted with superior seed and isolated, rogued, and inspected in order to provide seed stocks free from certain diseases.

Seed testing: growing representative samples of seed stocks in greenhouses or in southern regions so as to get a disease percentage reading before time to plant the seed stocks.

Spores: small reproductive bodies, of fungi, etc., that correspond to the seeds of ordinary plants.

Spots: discolored areas on leaves, stems, or tubers, or comparatively small discolored parts inside stems or tubers.

Stolon: a branch, usually underground, that normally produces one tuber.

Suberization: corking over or complete healing of cut seed pieces, requiring fresh, moist, and warm (60-70° F.) air.

Tuber indexing: the winter testing of a tuber by growing a plant from an eye, in greenhouse or southern clime.

Tuber unit: a series of consecutive hills growing from pieces of the same seed tuber.

Vascular ring: a layer not far below the skin of stem or tuber, appearing as a ring in a slice across the stem or tuber, serving in part as a pathway for solutions.

Veining: the comparatively transparent parts of a leaflet that form a network and serve for support and for transporting water and dissolved minerals and food.

Vine: the "top"; the combination of stem or stalk and the leaves borne by it.

Virus: (plural is viruses) a complicated chemical substance or very simple form of life consisting of particles that must grow at the expense of the potato plant and within it. A potato virus usually is transmitted from one plant to another in the sap by insects or by mechanical means, and usually is perpetuated from one crop to the next in the tubers of affected plants.

STANDARD CONTROL MEASURES

Resistance

Plants of the Sebago and Kennebec varieties are resistant to late blight. Katahdins are resistant to mild mosaic, rugose mosaic, latent

mosaic, net necrosis, and somewhat to leafroll. Irish Cobblers are resistant to mild mosaic. Chippewas are resistant to mild mosaic, rugose mosaic, and net necrosis. Sequoias are resistant to flea beetles and leafhoppers. Tetons are resistant to ring rot. Ontario and certain other new varieties are resistant to scab.

For discussion of varieties see References 12, 13, and 14 in the list at the end of this bulletin.

SEED TESTING

Samples of seed stocks are grown in Florida during the winter in order to get a disease percentage forecast before time to plant the seed stock. Inquiries and applications may be sent to the Maine Agricultural Experiment Station. The process applies especially to mosaic, leafroll, spindle tuber, and varietal admixture. The samples may also be grown in greenhouses if facilities are available. Tuber-indexing is a refined method whereby each tuber is seed tested.

For discussion of seed testing see Reference 14.

DISINFECTION

Seed Disinfection

Seed tubers may be disinfected ("treated") in late winter or in the spring before they sprout, if they are Irish Cobblers or Green Mountains with Rhizoctonia black scurf on them, to reduce Rhizoctonia injury to the stems. Katahdins, Sebagos, and Chippewas are more easily injured by seed disinfection than Cobblers and Mountains. Cold mercuric chloride solution is effective if its strength is maintained. Acid mercury solution remains effective for 25 usings without replenishment. Organic mercury dips are safer and easier than the solutions referred to, but generally are not quite so effective.

Cold mercuric chloride solution is made up and used as follows: Use nonmetallic containers (of wood, enamel, or concrete). Dissolve 4 ounces of mercuric chloride (corrosive sublimate) in 2 quarts of warm water. Add cold water to make up to 30 gallons. Immerse the tubers for 30 minutes to two hours. Dry them as quickly as possible. Use for only four immersions. *The solution is very poisonous to humans and animals, even after use.*

Acid mercury solution is made up and used as follows: Use nonmetallic containers. Dissolve 6 ounces of mercuric chloride (corrosive sublimate) in 2 quarts of warm water. Add one gallon of white distilled vinegar and enough cold water to make 25 gallons. Immerse the potatoes for 5 minutes and then dry as rapidly as possible. The solution

keeps its strength for 25 immersions or batches, each consisting of as many potatoes as the solution will hold and still cover them. *The solution is very poisonous to humans and animals.*

Organic mercury dips are used as instantaneous dips as recommended by the manufacturer. They can be used in metallic containers or on cut seed, but *are poisonous to humans and animals.*

For details on seed disinfection see References 12, 13, and 14.

Disinfection of Storages and Equipment

When storages and barrels, racks, diggers, planters, etc., have been used for a stock containing ring rot, their disinfection is necessary if contamination of healthy stocks is to be avoided. (See Reference 4.) After thorough cleaning, disinfection is possible with any one of the following water solutions:

Blue vitriol 2 lbs. to 10 gal.
Stock dip (phenol coefficient of 6) 1 gal. to 50 gal.
Organic mercury dips or acid mercury solutions as for seed disinfection.

The blue vitriol and acid mercury solutions cannot be used on metallic equipment or in metallic containers.

Soil Acidification

Potato scab in Maine is largely dependent upon soil conditions (see Reference 10). Sulphur or ammonium sulphate can be worked into soil that is "scabby" in order to make it more acid and therefore less scabby. Inquiries should be directed to the Soil Testing Laboratory, University of Maine, with respect to the securing of adequate soil samples, their analysis, and their significance as to the amount of sulphur or ammonium sulphate needed. It also would be helpful to grow and turn under green manure crops such as millet or clover.

Suberization or Healing

Fungi and bacteria can be kept from entering cut seed if the newly exposed tuber flesh is quickly and completely suberized or healed. This requires a combination of fresh, damp, air and a temperature of 50 to 70° F. for several days. Seed pieces cut in the field, as is often done in tuber-unit planting, heal satisfactorily if covered soon after being planted and if the soil is neither dry and hot nor very cold and wet.

For a discussion of suberization see References 12, 13, and 14.

SPRAYING AND DUSTING

Potato plants are sprayed or dusted with fungicides in order to control late blight and early blight. The best fungicide, all things considered, is Bordeaux mixture made as "instant Bordeaux." Various substitutes are often suitable, such as insoluble copper fungicides, organic fungicides, and copper-lime dust; in the absence of disease, these do not reduce the yield as much as Bordeaux mixture does. Insecticides are usually applied with fungicides rather than separately.

Bordeaux mixture also serves somewhat to control certain insects, such as flea beetles and leafhoppers. DDT is very effective against most insects.

Herbicides (weed-killing chemicals) are applied to potato plants rather late in the growing season in order to help control late-blight rot and virus diseases, and to certain weeds and bushes to help control insects which spread certain virus diseases of potatoes.

The use of fungicides, insecticides, and herbicides on the foliage is discussed in References 2, 3, 12, 13, and 14.

HANDLING AND GRADING TUBERS

If potatoes are handled so that there is less bruising and cracking, there is less waste in cooking and also less chance for certain rots to get a start. This is true both at digging time and during grading and packaging. When tubers have an unusually high water content or are cold, they are especially susceptible to bruising.

For further discussion see References 9 and 13.

STORING AND SHIPPING CONDITIONS

Higher temperature in storage and in transit increases late-blight rot if present; a low temperature of 32 to 36° F. not only reduces the development of this rot but in 30 to 60 days will "condition" the tubers so that the rot does not develop later at higher temperatures. Medium temperatures in storage (40 to 50° F.) favor the development of leafroll net necrosis and stem-end browning in susceptible varieties such as Green Mountain and Irish Cobbler. High temperature (70° F.) tends to prevent such development not only during the prevalence of such high temperature but also after 60 days holding at such temperature. Low temperature (32° F.) has the same effect. However, such low temperature causes, in time, mahogany browning in varieties such as Chippewa and Katahdin. Still lower temperatures cause a net necrosis, a ring necrosis, internal blotching, and leakers. Each fungus and bacterial rot responds to temperature differences in its own way.

High humidity, water, and liquid from diseased tubers favor the development of some diseases and modify the effects of other diseases.

For further discussion see References 9, 13, and 15.

Sanitation

In winters with sufficient snow cover, tubers left in the field can live and serve as sources of late blight, ring rot, and virus diseases. Cleaning up is necessary in storage bins before disinfection for ring rot is practical. Piles of cull tubers, in "potato dumps," require special treatment to reduce late blight and virus diseases. (See Reference 5.) Cull piles help the Colorado potato beetle to start infestations.

Rotation

Even if sanitary measures have removed all old tops and tubers, the Rhizoctonia fungus may accumulate in soil used year after year for potato growing. So may also the fungi Fusarium, Botrytis, Sclerotinia, and the causes of scab and pink rot. With the trend toward shorter rotations in Aroostook County, greater care is needed with respect to sanitation and seed disinfection in order to reduce the danger of soil infestation.

Seed Plots and Seed Certification

Potato fields of various sizes may be used as seed plots to provide seed stocks comparatively free from virus diseases, ring rot, and blackleg. Freedom from virus diseases is more nearly approached as the seed plot is planted with more healthy seed, is planted earlier, is larger, is more isolated, is planted by tuber-units, is rogued more carefully, and is dug earlier, or has the seed-producing plants killed earlier. Seed plots and other potato fields are certified by the State Department of Agriculture, Augusta, if they meet certain requirements upon inspection. The product of the best seed plots can be depended upon to produce certifiable fields and is called foundation stock. A foundation-seed program can be entered through application to the Maine State Seed Board. Certified seed in general produces fields with less disease than those planted with noncertified seed.

For further discussion see References 3, 6, 11, 13, and 14.

DISEASES CAUSED BY FUNGI, BACTERIA, AND VIRUSES

Late Blight and Late-Blight Tuber Rot. Cause: A fungus (*Phytophthora infestans*) the spores of which are disseminated by wind

and splashing rain and infect the plants only when wet by fog, dew, or rain. **Effects:** Leaf spots (Fig. 1A) that soon enlarge to an inch or more across, becoming mostly dark green, purple, dark brown, and black (often called "rust" by growers), with pale green border and a white mold or mildew on the lower leaf surface; drying out in sunny dry weather to become papery and brown with no mold. Stem lesions (Fig. 2A) covered with white mold. Tuber lesions (Fig. 3A, B) that are purple

FIGURE 1. A, leaf with late blight lesions. B, leaf with early blight lesions; flea beetle holes also present.

to reddish brown, penetrating irregularly into the flesh, sometimes drying out, often replaced in the soil and during storage and transit by bacterial soft rot and Fusarium rot. Epidemics in damp, warm weather that may completely kill all unprotected plants in a few days. Yield reduction through premature destruction of the shoots. Missing or weak hills when infected seed pieces are planted. **Control**[4]: Use a re-

[4] Some of the suggested control measures for this disease and other disorders may not be justifiable under the prevailing conditions.

Figure 2. Lesions on green stems: A, late blight; B, Rhizoctonia; C, gray mold.

sistant variety, such as Sebago or Kennebec. Avoid seed with the rot present. Eliminate cull piles. (See Reference 5.) Avoid soil containing overwintered tubers with the rot present. Spray or dust thoroughly with an effective fungicide. Kill diseased vines early. Postpone digging until the vines have been dead for several days or until they have been completely killed by frost. Keep storage temperature below 36° F. for 30 to 60 days, starting as soon as possible after digging.

Early Blight and Early-Blight Tuber Rot. Cause: A fungus (*Alternaria solani*) that usually attacks vines and leaves only when they approach maturity. **Effects:** Dark brown leaf spots (Fig. 1B) that usually enlarge with closely spaced parallel rings ("target-board effect")

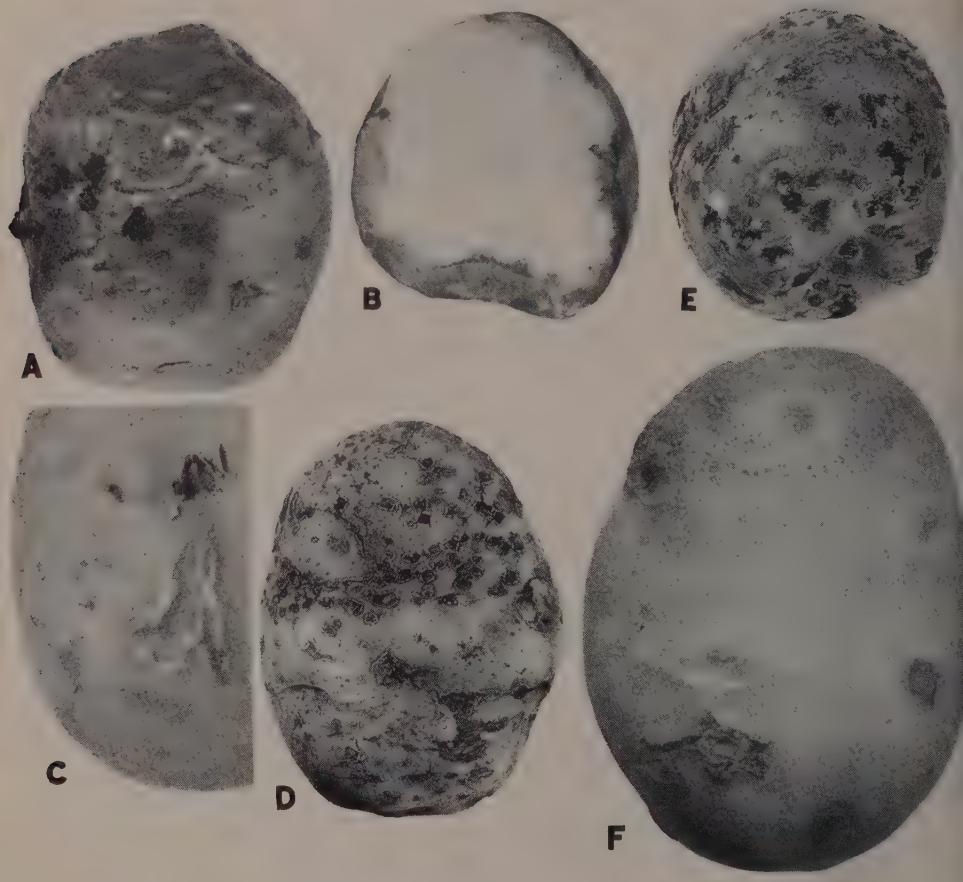

FIGURE 3. Tuber lesions: A and B, late blight; C, early blight (below stolon scar); D, powdery scab; E, deep scab; F, scab, and scab russeting at upper end.

until they reach leaf veins or margin. Tuber lesions (Fig. 3C) that are rounded, long, or branching, brown to purple, slightly sunken with raised margins, and usually small and shallow, sometimes opening the way for other rots. Yield reduction through hastening death of the vines. **Control:** Use all measures to maintain vigor of plants as long as possible. Avoid seed with the rot present. Avoid soil containing remains of affected vines. Spray or dust thoroughly with an effective fungicide. Do not use diseased vines to cap barrels of tubers left in the field. Keep storage temperature as low as possible without freezing.

Scab and Scab Russeting. Cause: A fungus (*Actinomyces scabies*)

that persists in alkaline soil, disappears from acid soil, and is favored by dry weather in scab-marginal soils. **Effects:** Tuber lesions (Fig. 3F) that are rounded, slightly raised, and rough, sometimes followed by tuber rot or deepened by the feeding of insects (Figs. 3E and 20A) and other small animals. Tuber roughening or russeting (Fig. 3F) like an oversize mild scab spot, with a very thin layer of pinkish white mold on the russeted skin when the tubers are first dug. **Control:** Use resistant varieties. With susceptible varieties, acidify soil where the crop has usually been scabby year after year. Avoid scabby tubers for

Figure 4. Rhizoctonia fungus: A, cutting off sprouts and girdling stems below soil surface; B, forming a brown layer of hyphal threads over the stem below soil surface, and a white spore-covered layer at the ground level (just above roots and near leaf).

seed, or disinfect them, if planting is to be done in soil that is practically free of scab and that is not acid enough to prevent the disease; such conditions occur probably only in newly cleared woodland. Also in such conditions avoid the application of manure, especially if it is from animals which have eaten scabby potatoes, and avoid dumping scabby cull potatoes on the land. Postpone liming the soil until information has been used from the Soil Testing Laboratory, University of Maine, with respect to the securing of adequate soil samples, their analysis, and their significance as to the amount of liming possible without favoring the development of scab. (See Reference 10.)

Powdery Scab. Cause: A fungus (*Spongospora subterranea*) that persists in cold, wet soil. **Effects:** Tuber lesions (Fig. 3D) that are small, circular, filled with a brown powder, and bordered by loose skin.

FIGURE 5. A, plant wilted from Rhizoctonia girdling. B, internal stem browning caused by the Verticillium wilt fungus (photograph by E. S. Schultz). C, stem decayed by the Sclerotinia fungus with its black overwintering sclerotia already formed. D, blackleg plant.

Warty outgrowths on tubers. External cavities in tubers. **Control:** Avoid low, wet soil where the disease is known to occur.

Rhizoctonia Disease. Cause: A fungus (*Rhizoctonia solani* (*Corticium vagum, Pellicularia filamentosa*)) that feeds on many kinds of plants and persists in the soil indefinitely. **Effects:** Dark brown lesions on the underground young white sprouts and stems, on the underground white parts of emerged stems, and on the lower parts of the green parts of the stems (Figs. 2B, 4A). Brown fungus threads on the stems (Fig. 4B) especially at and near the lesions. White mold (Fig. 4B) on the lower part of the green stem. Sometimes wilting (Fig. 5A), leaf rolling and yellowing, or thickening of the branches ("aerial tubers"), due to the girdling of the lower part of the stem.

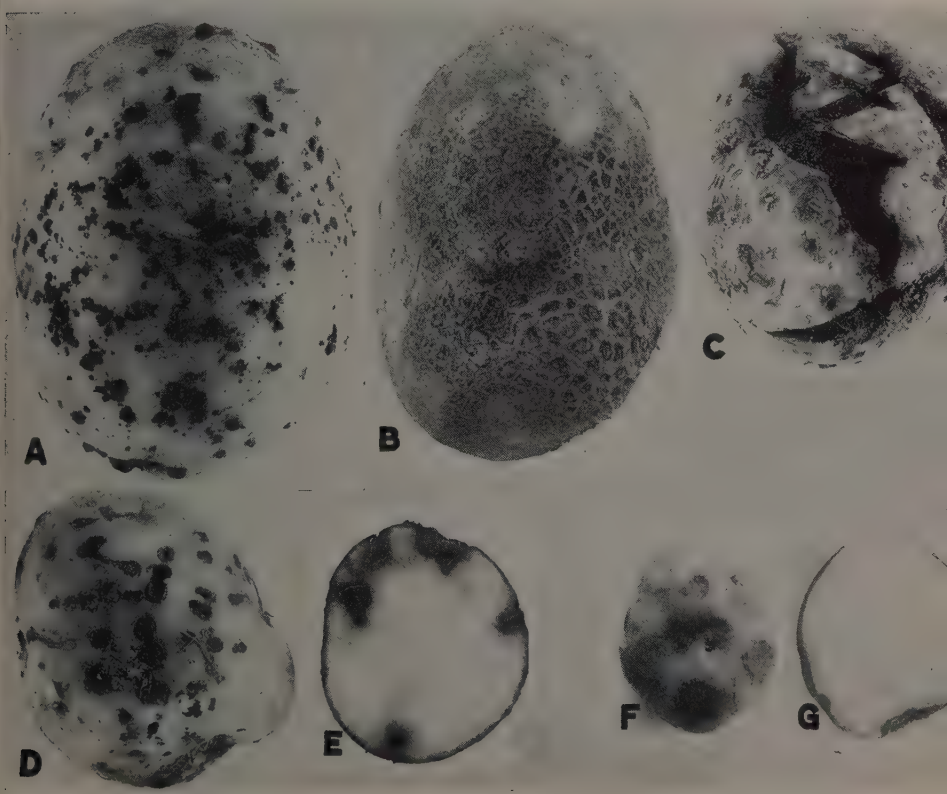

Figure 6. Rhizoctonia effects on tubers: A, black scurf; B, russeting; C, cracking; D and E, holes; F and G, shallow lesions.

Brown to black thin bodies ("black scurf") that adhere closely to the tuber skin (Fig. 6A). Tuber russeting (Fig. 6B) and cracking (Fig. 6C). Brown fungus threads on the tubers. Holes in the tubers (Fig. 6D,E). Sometimes shallow brown lesions (Fig. 6F,G) on the tubers or brown

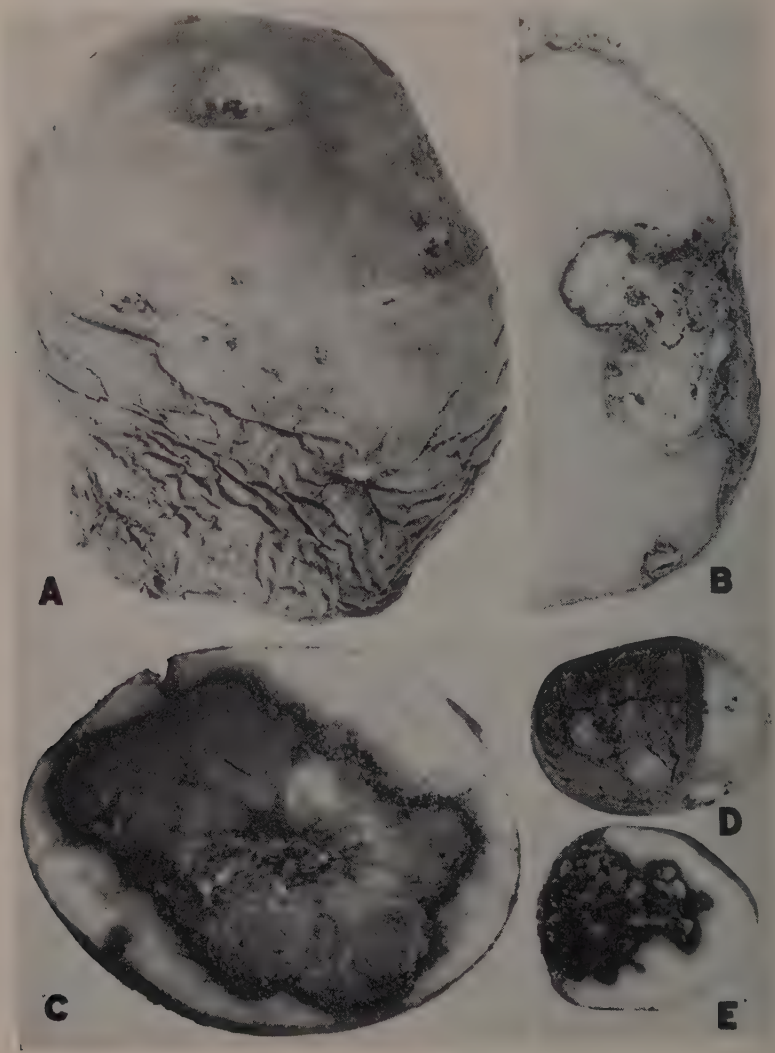

FIGURE 7. Tuber rots: A, gray mold; B, Phoma; C, Pythium or leak; D and E, Fusarium.

decay lining the tunnels made by wireworms. Lesions on the stolons. Missing, late-emerging, or weak hills. Increase in number of tubers and decrease in their size. **Control:** Use seed stocks with no black scurf present. If tubers are used with black scurf apparent, disinfect the tubers with a mercurial solution if not injurious to the variety. Use crop rotation with cereals or grasses as often as practical. Promote fast growth of the plants. Dig tubers as soon as they are mature.

Gray-Mold Blight and Gray-Mold Tuber Rot. Cause: A fungus (*Botrytis cinerea*) which attacks plants of many kinds. **Effects:** Light green lesions on the lower part of the green part of the stem (Fig. 2C). Watersoaked lesions on leaflets, especially where dead blossoms have lodged. Destruction of lowest leaves which become dark brown and covered with the gray mold. Occasionally a tuber rot starting at stolon end and progressing as a rather soft, flabby, watery dark rot

Figure 8. A, Verticillium wilt. B, ring rot wilt (photograph by H. A. Eddins). C, lightning injury in field. D, midday wilting of upper leaves from dry soil, dry weather, and cultivator pruning of roots.

(Fig. 7A). **Control:** Avoid dense vine growth and shading of lowest leaves.

Sclerotinia Disease. Cause: A fungus (*Sclerotinia sclerotiorum*) that attacks plants of many kinds. **Effects:** Occasional dead or dying plants with lower part of stem dried out and whitened and with roundish black fungus bodies inside or on surface (Fig. 5C). **Control:** Destroy diseased vines and avoid soil in which any crop, potato or other, has been affected.

Verticillium Wilt. Cause: A fungus (*Verticillium albo-atrum*) that persists in the soil and in tubers from diseased plants. **Effects:** Wilting (Fig. 8A) and dying of plants. Brown ring in lower part of stem (Fig. 5B) and in stolon end of tuber. **Control:** Rotate crops. Discard seed stocks containing the disease. Do not return diseased tubers to potato land. Avoid susceptible varieties.

Pink Rot. Cause: A fungus (*Phytophthora erythroseptica*) that persists in wet soil. **Effects:** Wilt and stem decay. Externally, dull finish to tubers, and blackened eyes. Internally, rubbery tuber flesh from which water can be squeezed easily, and which, when cut and exposed to the air turns pink and then darker until black. **Control:** Avoid contaminated soil and seed tubers.

Leak. Cause: A fungus (*Pythium debaryanum*) that causes damping-off of vegetable crops. **Effects:** Internal brown, watery rot of tubers, usually leaving a shell of unrotted flesh next to the skin (Fig. 7C). **Control:** Avoid soil where damping-off has occurred. Avoid wounding tubers and keep storage temperature low.

Fusarium Tuber Rots. Cause: Several fungus species (*Fusarium avenaceum, F. coeruleum, F. sambucinum* f. 6,) that persist in the soil, in rotted seed tubers, and in the dirt on seed tubers. **Effects:** Tuber surface sunken or wrinkled (Fig. 7D). Tuber flesh rot brown to black, wet to dry, often developing cavities containing white, pink, yellow, and red mold (Fig. 7E). Seed-piece rot and missing hills. Often starts in late blight tuber rot, early blight tuber rot, and bruise cracks. **Control:** Avoid infected seed and contaminated soil. Disinfect the seed tubers. Suberize cut seed. Avoid wounding tubers. Keep storage cool and dry.

Phoma Tuber Rot. Cause: A fungus (*Phoma tuberosa*) that starts growth in wounds and in lesions of other fungi. **Effects:** A brownish tuber and seed-piece rot (Fig. 7B) with sunken surface covered by remains of skin, and with flesh inside turned gray to black and shrinking from the tuber skin. Small raised black points on surface of lesion. **Control:** Prevent wounding tubers. Suberize cut seed.

Silver Scurf. Cause: A fungus (*Spondylocladium atrovirens*) that spreads from seed piece to new tubers in the soil and from one tuber to

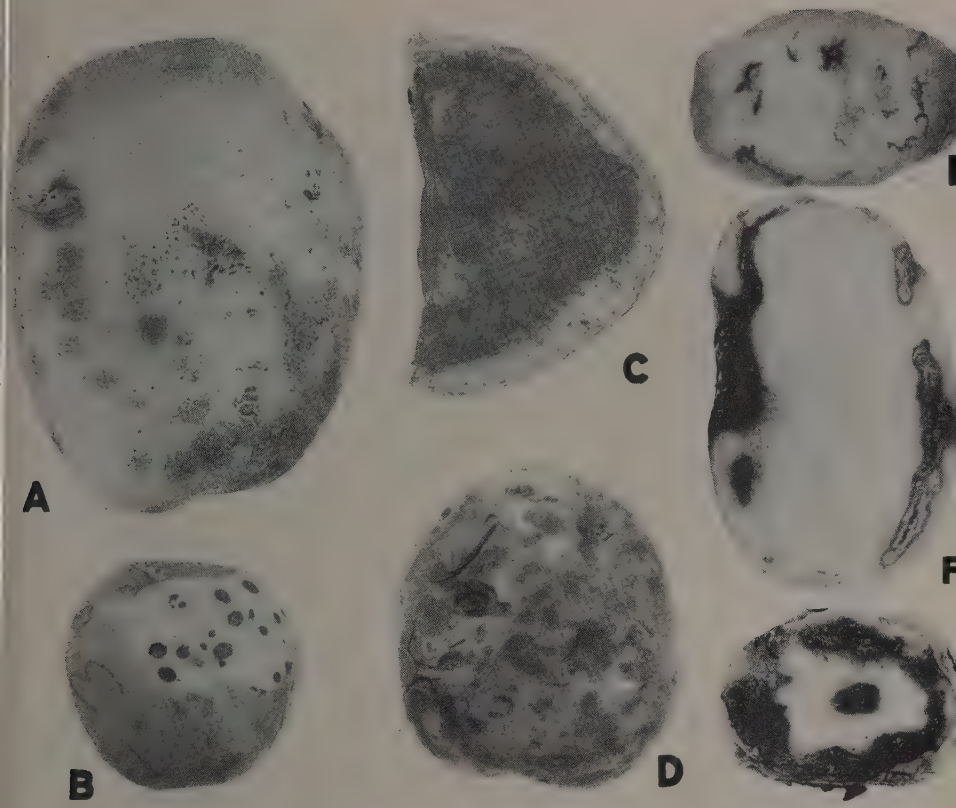

Figure 9. Silver scurf: A, new spots; B, old spots with lesions beneath. C, seed piece rot caused by soft-rot bacteria. D, disinfectant injury. Ring rot: E, cracks; F, lesions in split tuber; G, lesions in tuber cross section.

another in storage. **Effects:** Tuber surface spots (Fig. 9A) becoming about a fourth of an inch or more across, rounded, sometimes numerous enough to affect a continuous area; at first light brown, later becoming darker (like soot smudges) due to fungus spores; silvery or glassy looking when wet. Shrivelling and sinking of surface due to damage to tuber skin and consequent drying out (Fig. 9B). Lesions below spots (Fig. 9B). **Control:** Avoid seed tubers that have the disease. Dig tubers as soon as they are mature. Keep storage cold and dry.

Blackleg and Bacterial Soft Rot. Cause: Bacteria (*Bacillus carotovorus* (*B. solanisaprus, B. phytophthorus, B. atrosepticus, Erwinia phytophthora, Erwinia carotovora*)) that are generally present in soil and fungus lesions, and that are disseminated by knives, water, and certain

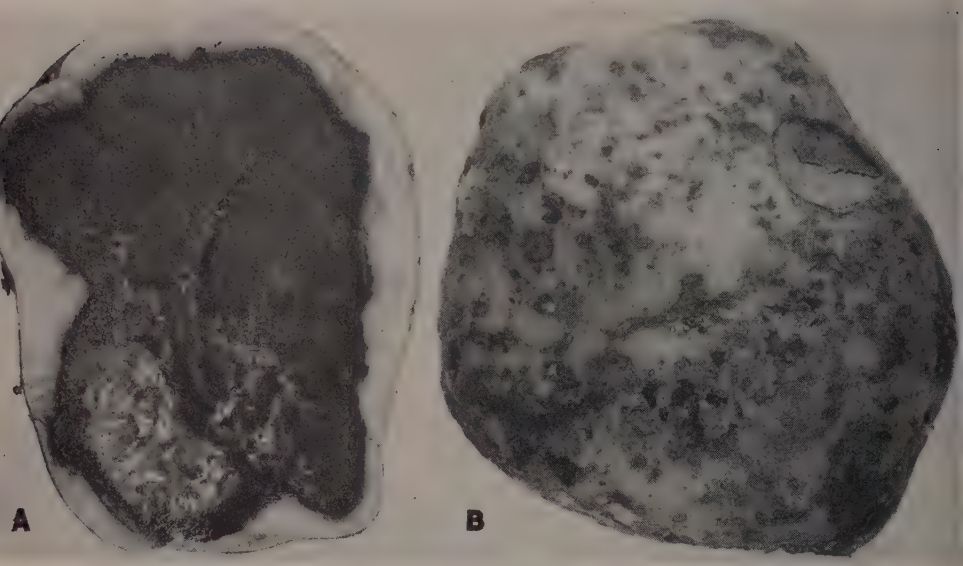

FIGURE 10. Bacterial soft rot: A, internal; B, surface pitting.

insects.[5] **Effects:** Soft rot of tubers (Fig. 10A) and seed pieces (Fig. 9C) starting where there is imperfect healing of cut surfaces, excess water, freezing injury, ring rot, etc., extending from seed pieces with soft rot to lower stems causing green to black, wet to dry rot of stems (Fig. 5D). Bunching, yellowing, rolling, and wilting of leaves. Dwarfing and early death of plants. Dark streaks in stems. Weak and missing hills. Internal streaking and rotting of new tubers of diseased hills, especially at stolon end. Pitting of tubers in wet storage (Fig. 10B). **Control:** Avoid seed tubers from diseased plants or with rot of any kind. Disinfect suspected seed tubers. Heal cut seed quickly. Plant by tuber units. Avoid soil in which blackleg plants grew the preceding season, if tubers in ground are still alive. Rogue out blackleg plants. Avoid injury to tubers by bruising, freezing, and excess moisture. Dry tubers quickly if washed. Keep storage cool and dry.

Ring Rot. Cause: Bacteria (*Corynebacterium sepedonicum* (*Phytomonas sepedonica, Aplanobacter sepedonicum, Bacterium sepedonicum*)) that overwinter in diseased tubers and are spread very readily by knives and other equipment. **Effects:** Vascular ring in tuber at first thinly rotted, when squeezed giving out yellowish white and cheesy

[5] Seed-corn maggot (*Hylemya cilicrura*) and potato-seed maggot (*H. trichodactyla*).

strings or ribbons. Later, interior of tuber rotted (Fig. 9F,G) often leaving a shell of firm flesh outside vascular ring. Cracks on outside of badly affected new tubers (Fig. 9E). Plants wilted (Fig. 8B) late in season, often dying. Leaves mottled, becoming pale green, dying. (See References 1 and 4.) **Control:** Plant resistant varieties such as Teton. Use seed stock with a perfectly clean record for several years past. Disinfect all knives, graders, planters, barrels, sacks, and bins that have been in contact with diseased or suspected tubers. (See Reference 4.) Keep storage cold. Avoid planting in fields containing overwintering tubers with ring rot. Use certified or foundation seed.

Red-Xylem Disease. Cause: Probably bacteria, not yet identified. **Effects:** Reddish brown vascular ring in tubers. Graying in dehydrated

Figure 11. Green Mountain leaves: A, mild mosaic; B, rugose mosaic spotting and streaking on lower surface, from new infection.

potatoes. Lesion at stolon scar. Hollow heart extending in from stolon scar. Reddish watersoaked flesh adjoining lesion and hollow heart. Shallow rot of seed piece. **Control:** Avoid susceptible varieties, including Irish Cobblers, Katahdins, and Sebagos.

Mild Mosaic. Cause: A combination of viruses (Potato virus A and potato virus X; *Solanum* virus 3 and *Solanum* virus 1; *Marmor solani* and *Marmor dubium*) whose characteristic effects on leaves are obscured by hot weather. **Effects:** Leaf mottling and crinkling (Fig. 11A).

FIGURE 12. Green Mountain plants: A, leafrolling mosaic; B, rugose mosaic; C, spindle tuber; D, healthy.

Dwarfing of plants. Yield reduction. **Control:** Avoid Green Mountains and Bliss Triumphs or, in these two varieties, plant certified, foundation or tested seed. Use seed plots. Avoid soil containing overwintering tubers with the disease. Harvest seed, or kill seed-producing plants, early. The Chippewa, Houma, Irish Cobbler, Katahdin, Mohawk, and Sebago varieties are resistant.

Crinkle Mosaic. Cause: This is a virus disease much like mild mosaic and for practical purposes may be considered a more conspicuous strain of mild mosaic. **Effects:** Mottling and severe crinkling of the leaflets. Dwarfing of plants. Yield reduction. **Control:** As for mild mosaic.

Leafrolling Mosaic. Cause: This is a virus disease much like mild mosaic. **Effects:** Mottling and slight rolling and crinkling of leaflets (Fig. 12A). Yield reduction. Combines with spindle tuber to form a mottled curly dwarf. **Control:** As for mild mosaic.

Rugose Mosaic. Cause: A combination of viruses (Potato virus Y and potato virus X; *Solanum* virus 2 and *Solanum* virus 1; *Marmor cucumeris* var. *upsilon* and *Marmor dubium*) whose characteristic effects on leaves are obscured by low temperature. **Effects:** Mottling, yellowing, rugose wrinkling, burning, streaking, and dropping of leaves (Figs. 11B and 12B). Dwarfing and early death of plants. Severe yield reduction. **Control:** Plant certified, foundation, or tested seed, or plant Chippewas or Katahdins, both of which are resistant. Avoid soil containing overwintering tubers with the disease. Use seed plots. Harvest seed early or kill seed-producing plants early.

Latent Mosaic. Cause: A virus (Potato virus X; *Solanum* virus 1; *Marmor dubium*) present in all healthy-appearing plants of the older varieties usually without apparent effect upon the leaves. **Effects:** Sometimes slight mottling of leaflets. Yield reduction. **Control:** Plant resistant varieties such as Katahdin, or latent-free seed stock from the State Potato Seed Board.

Interveinal Mosaic. Cause: This is a virus disease very difficult to detect except when affected plants have grown rapidly in moist, cloudy weather. **Effects:** Slight mottling of the leaflets between the veins. **Control:** Avoid affected seed stocks.

Leafroll and Leafroll Net Necrosis. Cause: A virus (*Solanum* virus 14; *Corium solani*) transmitted from one plant to another only by insects, especially green peach aphids. **Effects:** Rolling, yellowing, and stiffness of leaflets, starting in the lowest leaves after tuber perpetuation (Fig. 13A) and sometimes in the upper leaves after aphid transmission. Erectness of leaves. Dwarfing of plants. Net necrosis (Fig. 14A) in tubers of some varieties. Spindling sprouts (Fig. 14C).

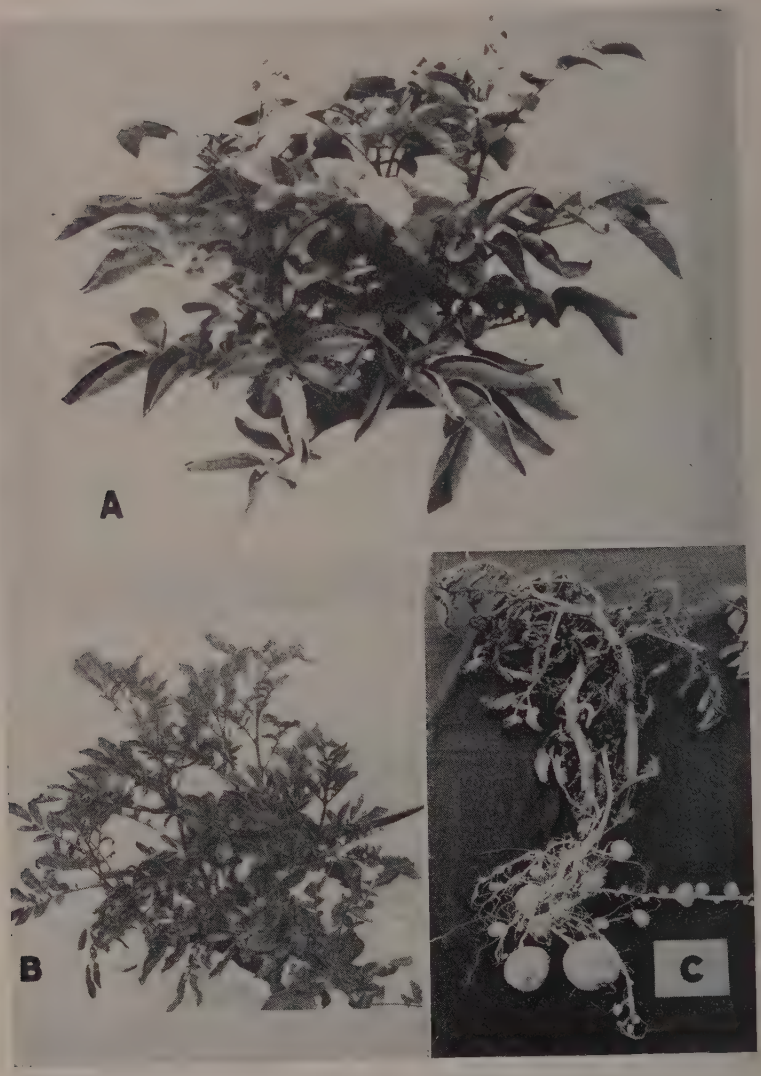

FIGURE 13. Plants with: A, leafroll; B, yellow top; C, purple top.

Considerable decrease of yield. **Control:** Plant certified, foundation or tested seed. Use seed plots. Use less phosphorus, potash, and chlorine in fertilizers. (See Reference 8.) Avoid soil containing overwintering tubers affected with the disease. Kill certain weeds and shrubs (see References 2 and 11). Harvest seed early or kill seed-producing

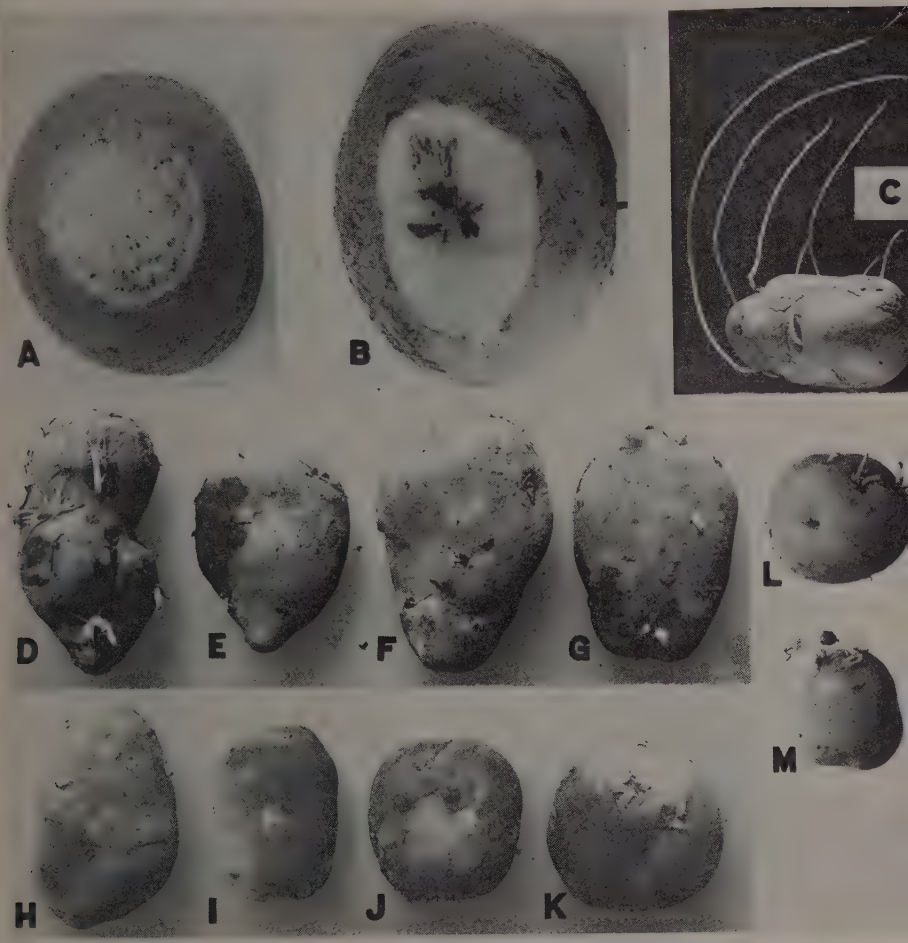

Figure 14. Green Mountain tubers: A, leafroll net necrosis; B, stem-end browning; C, leafroll spindling sprout; D, spindle tuber; E to K, mostly off-type, though healthy. Katahdin purple top tubers: L, with spindling sprouts; M, with sprout tubers.

plants early. Against the net-necrosis phase, use Katahdins and Chippewas rather than Green Mountains, and store Green Mountains for 60 days at 33° F. or at 70° F. starting immediately after digging.

Stem-End Browning. Cause: Apparently a virus. **Effects:** Reddish brown to black streaks in tubers at stolon end (Fig. 14B). **Control:** Use Katahdins and Chippewas rather than Green Mountains, or, in Green

Mountains, use seed from strain with clean record or store crop for 60 days at 33° or at 70° F. starting immediately after digging. Use less phosphorus, potash, and chlorine in fertilizers. (See Reference 8.)

Spindle Tuber. Cause: A virus (*Solanum* virus 12; *Acrogenus solani* var. *vulgaris*) transmitted by knives and picker planters as well as by insects. **Effects:** Erectness, spindliness, and dwarfing of plants. Smallness and erectness of leaves (Fig. 12C). Darker green and sometimes rolling and twisting of leaflets. Cylindrical middle and tapering ends of tubers (Fig. 14D). Tubers smoother, lighter colored if red, and with a more tender skin. More tender tuber flesh. Tuber eyes more numerous, more conspicuous, and shallower. Yield reduction. Occasional "growth cracks" in tubers. Tuber flesh of Green Mountains soggier when cooked. Lateness of sprouting. Sometimes spindling sprouts. **Control:** Plant seed that is free from the disease. Avoid soil containing overwintering tubers with the disease. Use seed plots. Harvest seed early or kill seed-producing plants early.

Unmottled Curly Dwarf. Cause: A virus (*Solanum* virus 13; *Acrogenus solani* var. *severus*) much like that of spindle tuber. **Effects:** Like those of spindle tuber except for their being more pronounced and being added to by curling of the leaflets, frequent cracking of the tubers lengthwise during growth with healing of the cracks to form growth cracks, brown streaks in the stem, and brown flecks in the flesh of the tuber. (See Reference 7.) **Control:** As for spindle tuber.

Yellow Top. Cause: A virus probably closely related to those of witches' broom, apical leafroll, and aster yellows.[6] (See Reference 7.) **Effects:** Yellowing, rolling, and stiffness of upper leaves (Fig. 13B). Death of some roots and brown vascular ring in lower part of stem. Branches of some stems thickened into small tubers. Many small tubers strung along stolons ("necklace effect"). Tuber net necrosis beginning during growing season. After infected tubers are planted, many spindling yellow sprouts, or missing hills. **Control:** Unknown.

Purple Top. Cause: A virus probably closely related to that of yellow top.[7] **Effects:** Purpling, yellowing, rolling, and stiffness of upper leaves. Premature death of foliage and of some roots. Many small tubers strung along stolons ("necklace effect") (Fig. 13C). Yield reduction. Some tubers wilted and spongy. Spindling sprouts (Fig. 14L)

[6] Yellow top virus and potato apical leafroll virus are known as *Solanum* virus 17; witches' broom virus is known as *Solanum* virus 15 and as *Chlorogenus solani*; aster yellows virus is known as *Callistephus* virus 1 and *Chlorogenus callistephi* var. *vulgaris*.

[7] Purple top is found in Maine in varieties, like the Katahdin, that do not have net necrosis where Green Mountains do, while yellow top and its net necrosis are found chiefly in Green Mountains.

and missing hills. Sprout tubers (Fig. 14M). **Control:** Apply DDT. Rogue out diseased hills.

INSECTS

Springtails (species in family Sminthuridae of the order Collembola). Small, active, dark-colored insects that jump like fleas or flea

Figure 15. A, Colorado potato beetle (potato bug). B, potato flea beetle. C, potato leafhopper. D, tarnished plant bug. E, click beetle (adult of wireworm). F. blister beetle. G. Euschistus bug. (A to G all about life size.) H. tarnished plant bug, somewhat enlarged; from photograph by DuPont Co. I, potato flea beetle; J, potato leafhopper; both considerably enlarged, photographs by DuPont Co. of drawings by A. Rudolphi. K, cutworms; L, white grub; M, wireworms; all slightly enlarged.

beetles when disturbed. Abdomen rounded and large in relation to the rest of the body. **Effects:** Small feeding punctures in the first few leaves that appear above ground. **Control:** Not necessary, especially if DDT is applied to control first brood of flea beetles.

Grasshoppers (species of the family Acrididae of the order Orthoptera). Well-known insects that eat many kinds of plants. **Effects:** Destruction, through eating, of leaflets or parts of leaflets. **Control:** Serious damage is uncommon. The regular insect control program should suffice.

Blister Beetles (species of the genus *Epicauta* of the order Coleoptera) (Fig. 15F). The "old fashioned potato bugs" which are usually gray or black, long and narrow and very active. The young of these beetles feed on grasshopper eggs in the soil. **Effects:** Leaves chewed by the beetles, often only on occasional plants, and destroyed except for the ribs. Leaves not completely destroyed are usually left with very irregular margins. **Control:** Spray or dust with DDT, rotenone or an arsenical. Injury is rather rare and sporadic but may be severe in small areas of a field.

Colorado Potato Beetle (*Leptinotarsa decemlineata* (Say)) (Fig. 15A). The once common "potato bugs" with yellowish and black stripes running lengthwise of their rounded bodies. Their reddish larvae cause most of the damage to potatoes. **Effects:** Leaves are chewed but not often destroyed by the adults. Leaves are usually destroyed, except for the ribs, by the larvae. **Control:** Spray or dust early with DDT to kill the adults before eggs can be laid and continue to apply DDT if necessary due to hatching of young. Rotenone or calcium arsenate may be used but they are less effective than DDT against the adults.

Potato Flea Beetle (*Epitrix cucumeris* (Harris)) (Fig. 15B, I). Small, black, very active beetles that jump like fleas as they take off for flight. **Effects:** Small holes in or through leaflets (Fig. 16A). Premature death of leaves. Reduction in yield rate. More early blight. In tubers, infrequent injury by larvae resulting in tunnels and trails, some going straight in from the skin and forming short, brown, hard slivers. Pimples and other roughnesses on skin. More scab and Rhizoctonia in tubers. **Control:** Use DDT alone, as soon as plants show injury, to prevent egg laying. Use DDT with a fungicide for late brood.

Tarnished Plant Bug. (*Lygus oblineatus* (Say)) (Fig. 15D, H). Active brownish bugs, mottled with various shades of yellowish and reddish brown; also their greenish nymphs. **Effects:** Leaflets and tips of shoots wilted (Fig. 16B), or leaflets rolled (Fig. 16C) and reddish with swollen stems. Proliferation of shoots below site of previous

Figure 16. A, flea-beetle holes in leaf. Tarnished plant bug injury: B, leaflet wilted; C, leaflets rolled.

injury. Early injury may modify growth habits of plant. **Control:** No really effective control known. Use of rotenone or DDT will reduce injury.

Four-Lined Plant Bug (*Poecilocapsus lineatus* (F.)). Quick moving, sucking insects, apple-green in general color, with four black stripes lengthwise of the wing covers and thorax. **Effects:** Groups of small round holes in leaflets. Not common. **Control:** Unnecessary.

Euschistus Bug (*Euschistus tristigmus* (Say)) (Fig. 15G). Larvae and adults of a dark brown, broadly oval stink bug. **Effects:** Puncturing of stem with subsequent collapse (Fig. 17B). Uncommon. **Control:** Usual control measures for other insects should be sufficient.

Potato Leafhopper (*Empoasca fabae* (Harr.)) (Fig. 15C, J). Active, sidling or flying small light green, wedge-shaped sucking insects, nymphs and adults, found on the lower surfaces of leaflets. **Effects:** Leaf

FIGURE 17. A, potato aphids on upper part of shoot. B, stem portion collapsed from puncture by Euschistus bug. C, fertilizer burning of roots.

tip and marginal burning (Fig. 18A) due to toxin inserted into leaf tissue by the insects. Rolling of leaves. Yellowing of injured foliage. Premature death of foliage. Yield losses. **Control:** Apply Bordeaux mixture, DDT or pyrethrum.

Buckthorn Aphid (*Aphis abbreviata* Patch). Sucking plant lice, lemon yellow in color, found mostly on the lowest leaves of the potato

Figure 18. A, leaf burning from potato leafhopper feeding. B, spray injury (arsenical) to leaf.

plant. This is the smallest and least active of the four aphids found on potatoes. Usually most abundant in fields located near its primary host, buckthorn (*Rhamnus*). **Effects:** Reduction in yield through premature killing of vines especially in dry seasons. Transmission of some virus diseases. **Control:** Apply DDT throughout the season starting when the plants are quite small. Eradicate buckthorn bushes from surrounding territory with herbicides or other means. (See References 2 and 11.)

Potato Aphid (*Macrosiphum solanifolii* (Ashm.)[8]) (Fig. 17A).

[8] Also referred to under the names of *Illinoia solanifolii* (Ashm.) and *Macrosiphum gei* (Koch).

Sucking "plant lice" that are either pink or green. Usually found near the tops of plants and if numerous may cover the flower stalks. This is the largest of the four aphid species found on potatoes. Overwinters in egg stage on rose bushes. **Effects:** Curling, mottling, wrinkling, streaking and premature death of leaflets. Sticky "honey dew" on upper leaf surfaces. Sometimes, if very abundant, premature death of plants. Yield reduction. Transmission of some virus diseases. **Control:** Apply rotenone or nicotine. DDT is less effective against this aphid than it is in the case of the other three species. It will reduce an infestation if used early and continued throughout August. Eliminate rose bushes, both wild and cultivated, in the vicinity of potato fields.

Foxglove Aphid (*Myzus convolvuli* (Kltb.)). Sucking "plant lice," usually green in color, that start the season by hatching from eggs overwintered on common garden foxglove and probably other plants. **Effects:** Transmission of virus diseases. **Control:** This aphid is seldom abundant and can be controlled with the regular application of DDT. It is the least troublesome of the four aphid species found on potatoes.

Green Peach Aphid (*Myzus persicae* (Sulz.)). Sucking "plant lice" that are either hay colored or pink when wingless and predominantly black when winged. Peach aphids range somewhat larger than buckthorn aphids and somewhat smaller than potato aphids. This aphid tends to inhabit the lower half of the potato plant. **Effects:** Curling, mottling, wrinkling, streaking and premature death of leaflets. Sticky "honey dew" on upper leaf surfaces when abundant. Premature death of plants especially in dry seasons. Yield reduction due both to fewer and to smaller tubers. Transmission of virus diseases especially leafroll. Responsible for net necrosis in susceptible potato varieties, through spreading of leafroll. **Control:** DDT applied early and continued throughout the season will prevent loss in yield but will not always control leafroll spread. Eliminate wild plum (*Prunus nigra* Ait.) thickets by means of herbicides or otherwise. Control weeds in potatoes and elsewhere, especially kale and mustard. (See References 2 and 11.)

Stalk Borers (*Papaipema nebris* (Guen.) or related species). The larvae of certain moths. **Effects:** The larvae tunnel lengthwise in the center of the stem, causing it to wilt above the injury. **Control:** Usually unnecessary due to rarity of injury. Clean cultivation around the borders of a field to destroy large stemmed weeds will help.

Cutworms (various species of Noctuidae) (Fig. 15K). The larvae of certain kinds of moths. **Effects:** Plants cut off near soil surface or

wilting due to stems being eaten into near soil surface. **Control:** If serious, cutworm bait may be used in affected areas in a field. Generally unimportant.

White Grubs (species of *Phyllophaga* or *Lacnosterna*) (Fig. 15L). The fat, white, curled, brown-headed larvae of May-beetles (June bugs). **Effects:** Parts of tubers eaten out, with the widest part of the cavity at the surface of the tuber (much as in Fig. 20C). **Control:** Avoid planting on old sod ground. Rotation of crops will prevent injury.

Wireworms (species of Elateridae) (Fig. 15M). The white to brown wiry larvae of click beetles (Fig. 15E). **Effects:** Holes and tunnels in seed pieces and tubers (Fig. 19A,B). Weak and missing hills. **Control:** Avoid planting on old sod ground. Cultivate cleanly. Use a short rotation. Keep informed of the progress being made in soil fumigation for these and other soil inhabiting pests.

Midge Flies (*Camptocladius* sp.). The larvae (maggots) of a small fly. **Effects:** Tunnels in tubers (Fig. 19C, D). **Control:** Unimportant because of rarity.

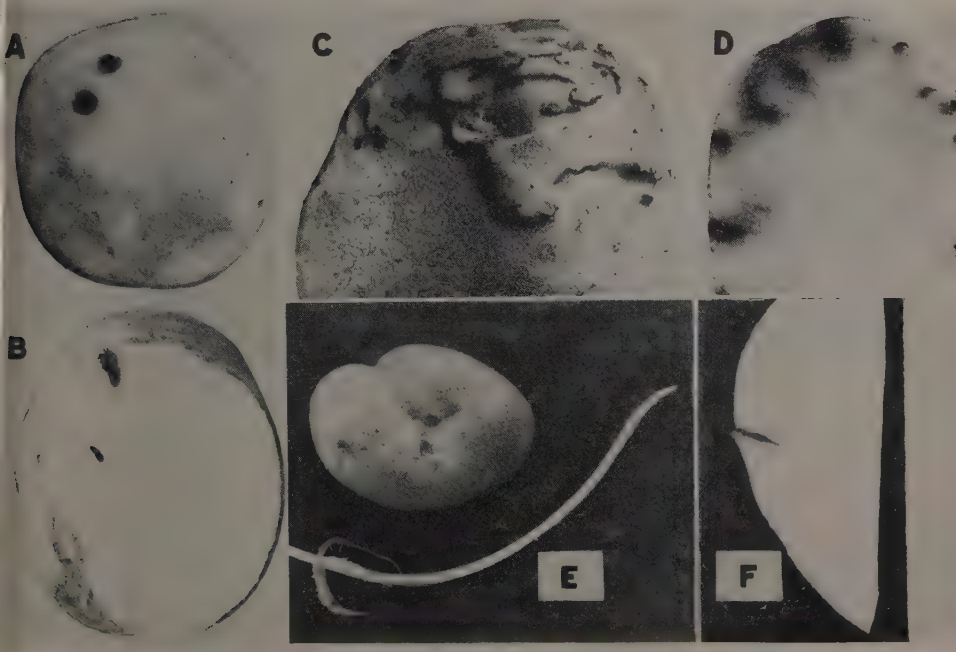

Figure 19. A and B, wireworm holes. C and D, tunnels made by midge fly larvae. E, growing end of witch grass rhizome and hole made by it in left-hand portion of tuber slice. F, hole made by growing end of witch grass rhizome.

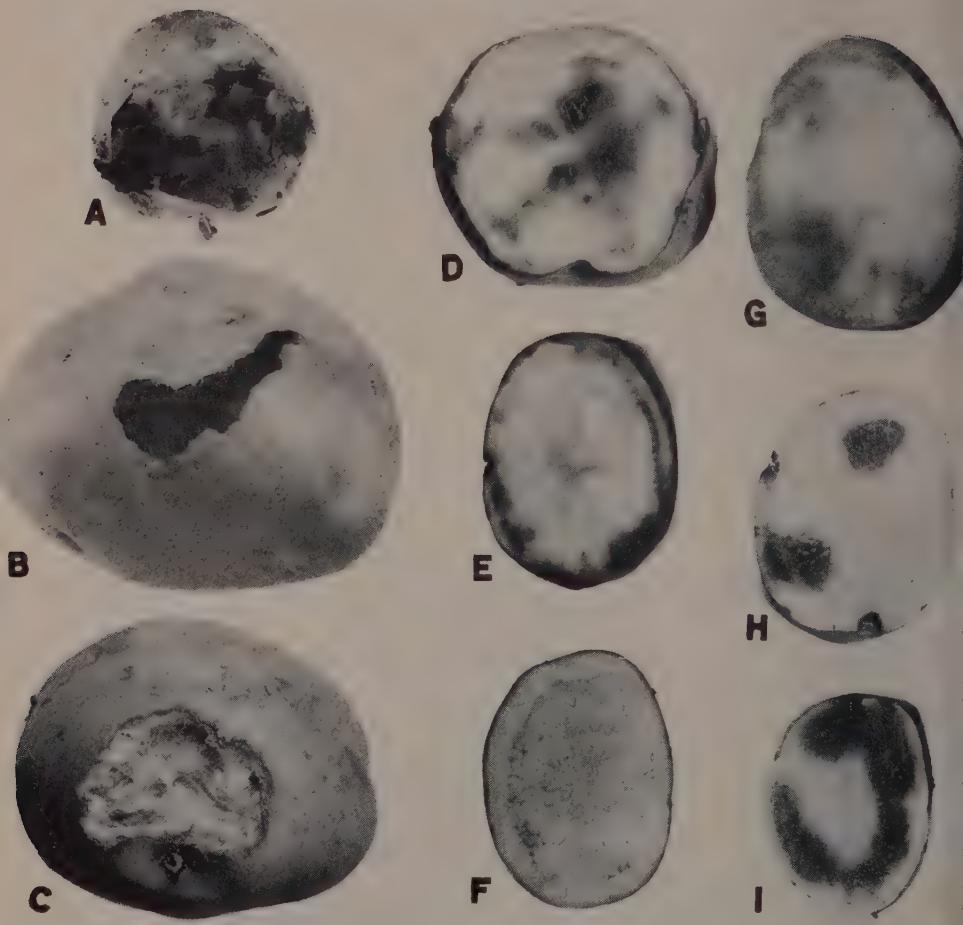

FIGURE 20. Tuber cavities made by: A, fungus gnats; B, slugs; C, field mice. Injuries from rapid freezing: D to F, blotch, ring, and net blackening, and cracks. G to I, browning from near-freezing temperature maintained for several months.

Fungus Gnats (*Pnyxia scabici* (Hopk.)). The larvae (maggots) of a small fly. **Effects:** Deepening of scab spots on tubers (Fig. 20A). **Control:** Avoid scab in tubers.

Seed Corn and Potato Seed Maggots (*Hylemya cilicrura* (Rond.) and *Hylemya trichodactyla* (Rond.)). The larvae (maggots) of certain small flies. **Effects:** Seed pieces tunneled, destroyed, and infected with bacteria that later cause blackleg. **Control:** Heal seed pieces before

planting, or plant them directly into the soil as cut. Be careful to dispose of all rotten or decayed tubers.

INJURIES BY ANIMALS OTHER THAN INSECTS

Slugs. Shell-free land snails (*Arion hortensis* Ferrussac). **Effects:** Holes in leaves. Parts eaten out of tubers, usually deeply with some skin left over the cavity (Fig. 20B). **Control:** Use metaldehyde-poisoned bait.

Mice and Rats. Field mice and common domestic mice and rats. **Effects:** Portions of tubers eaten out with paired grooves (tooth marks) conspicuous in the cavities (Fig. 20C). **Control:** Use poisoned bait, cats, dogs, and traps.

Mites. Small milky-colored eight-legged spider-like animals (Acarina). **Effects:** Portions of tubers eaten out where scab or decay has occurred. **Control:** Dispose of scabby or decayed tubers.

Millipedes. Hard, slender, gray to purple-brown worm-like animals (*Diploiulus londensis* var. *caerulcocinctus* (Wood)) that curl up with their dozens of legs inside the curve. **Effects:** Holes and tunnels in seed pieces and tubers. **Control:** Harvest crop early if infested.

Crows. Common crows. **Effects:** Small plants pulled up and sharp-angled holes eaten out of attached seed pieces. **Control:** If in small special seed plots, maintain high ridges early in season.

INJURIES BY NATURAL WEATHER AND SOIL CONDITIONS

Freezing Injury. Cause: Sudden drop in temperature below point tolerated by exposed parts of shoots or tubers. **Effects:** Leaves first watersoaked and wilted, then drying and blackened. In tubers (Fig. 20, D to F), net necrosis, dark blotching, ring darkening, internal cracks, and "leaker" stage wherein the tuber lacks firmness and loses water easily. Weak and missing hills if affected seed is used. **Control:** Avoid temperatures below 29° F.

Mahogany Browning. Cause: Continued low temperatures in storage. **Effects:** Spots, blotching, and solid discoloration, reddish brown to black, in tuber flesh (Fig. 20, G to I), sometimes showing through skin. Cracks in discolored flesh. Usually brownish in Katahdins and Chippewas, sometimes black in Green Mountains, Irish Cobblers, and Sebagos. Weak and missing hills if severely affected seed is used. **Control:** Avoid several months' storage at 35° F. or colder for Katahdins and Chippewas, and of 32° F. or colder for Green Mountains, Irish Cobblers, and Sebagos.

Sunscald of Leaves. Cause: Bright sunlight on young leaves, especially after a spell of cloudy weather, or on inverted older leaves. **Effects:** Parts of leaflets between ribs become a different shade of green and become wilted, especially in right-angle exposure to sun's rays, in a few hours and then dry out and become light brown. Silvering of lower leaf surface if turned up toward sunlight. **Control:** Not important.

Tipburn. Cause: Slow drying out of leaflets. **Effects:** Yellowing, dying, and darkening of leaflets from tips and margins inward (Fig. 18A). **Control:** Conserve soil water. Control leafhoppers, flea beetles, aphids, virus diseases, and early blight, all of which cause tip burn or make it worse.

Tuber Greening. Cause: Sunlight or other light on parts of tubers. **Effects:** Tuber parts green, bitter, and perhaps poisonous. No harmful effect on seed value. **Control:** Avoid Katahdins, which crack open the soil and become exposed to sunlight. Keep tubers hilled up to cover tubers. Avoid light on tubers in storage or market.

Lightning. Cause: "Bolt" striking ground and plants. **Effects:** Stems "cooked" and drying out to a light brown at and near surface of ground. Plants wilting and dying above stem injury. Injured plants usually limited to round area 10 to 20 feet across (Fig. 8C), but shape of affected area may be modified by bolt splitting or by bolt passing up to 100 feet or farther along rows when water is standing between them. Tubers "cooked" at attached end or inside and becoming soft-rotted or black or both. **Control:** Impractical and not important.

Hail. Effects: Cuts in leaflets. Light tan scars on stems. Sometimes breaking of stems and destruction of leaves.

Dry-Weather Wilting. Cause: Not enough soil water or root system to make up for evaporation from leaves. **Effects:** Upper young leaves limp and drooping, rolled (Fig. 8D), usually recovering upon increase of soil water or decrease of sunlight or wind. **Control:** Avoid root pruning with cultivators. Eliminate weeds. Irrigate.

Excess of Soil Water. Too much soil water for oxygen requirements of seed pieces or roots. **Effects:** Seed-piece rot. Weak and missing hills. Rolling, uprightness, and yellowing of leaves, occurring only in low, wet areas and in all plants there. Wilting of leaves when plants are standing in water. Enlarged lenticels on seed pieces and new tubers, like very small and regularly spaced scab spots. **Control:** Avoid planting in areas known to be subject to wetness.

Tuber Growth Cracks. Cause: Internal stresses, cracking near tuber surface, and healing. **Effects:** Widened external cracks that usu-

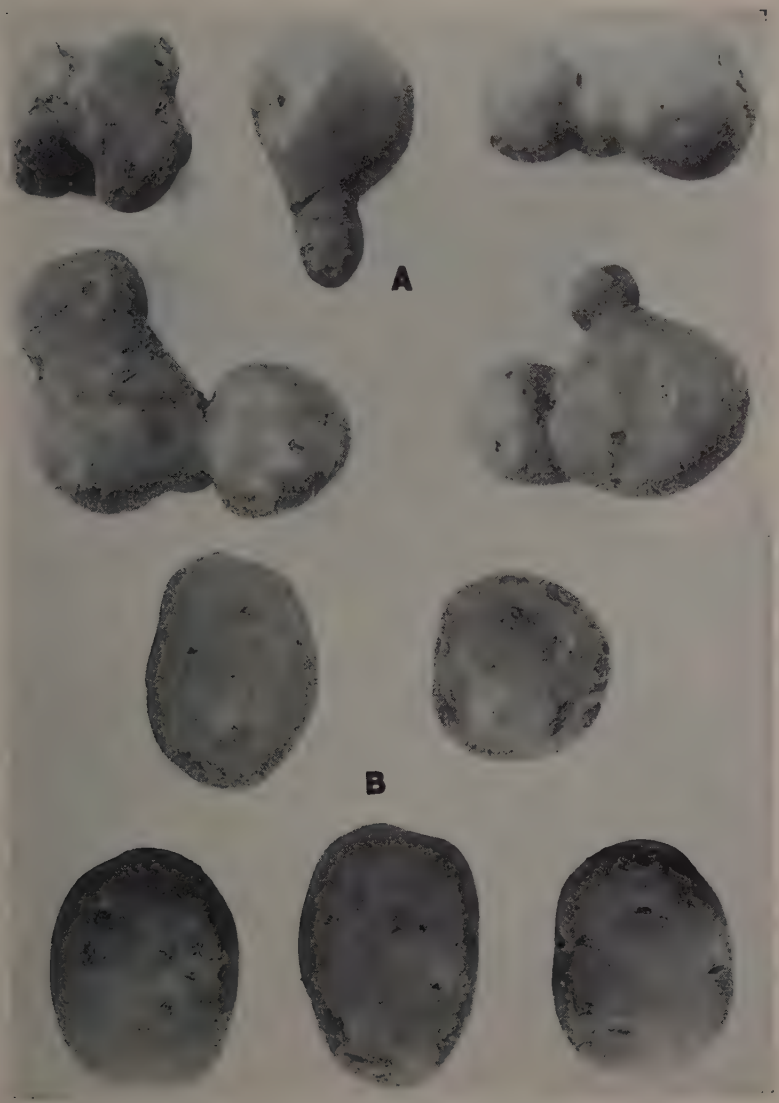

Figure 21. A, five off-type tubers used as seed. B, five tubers representing progeny of off-type tubers of A.

ally are healed by digging time (Fig. 24A). **Control:** Avoid spindle tuber. Otherwise not important.

Hollow Heart. Cause: Internal stresses that overcome capacity of

center of tuber to hold together. **Effects:** Cavity with brown lining, in center of tuber (Fig. 22A), starting with death of a small amount of the pith from which an internal crack develops. **Control:** Prevent uneven rate of tuber growth and large size of tubers. Avoid Sequoias, Katahdins, Irish Cobblers, and Russet Rurals.

Witch Grass Injury. Cause: Sharp growing points of grass rhizomes (*Agropyron* spp.) forcing way into tubers and even through them (Fig. 19E, F). **Effects:** Straight or slightly curved tunnels into and through tubers, often with grass rhizome still present.

Off-Type Tubers. Cause: Soil contents and growing conditions unsuitable for good tuber type in some varieties. **Effects:** Pointed stolon ends, pointed sprout ends, knobs, etc. (Figs. 14, E to K, and 21). **Control:** Avoid Green Mountains, rocky or hard soil, and uneven growing conditions.

INJURIES BY MAN-MADE CONDITIONS

Spray Injury. Cause: Insecticidal, fungicidal, or herbicidal chemicals that are too strong for the leaf surface and tuber interior. **Effects:** From arsenic, light tan rounded spots on leaves (Fig. 18B). From Bordeaux mixture applied in hot sun, a temporary wilting of leaves often accompanied by some crisping and dying of leaf between the ribs, or a bronzing where leaf surface is rubbed by tip or edge of another leaf. From herbicides, sometimes a vascular ring browning and cavities and lesions in the tubers (Fig. 22, B to H). Yield reduction by some fungicides in case there is no disease to control. **Control:** Avoid the cause.

Disinfectant Injury. Cause: Fungicidal or bactericidal chemicals that are too strong for the tuber surface as used in seed treatment. **Effects:** Round spots and pits at eyes and between, on tuber surface (Fig. 9D). Missing hills. **Control:** Avoid tender varieties (such as Chippewa, Katahdin, and Sebago). Use other means of control for diseases.

Fertilizer Burning. Cause: Improper placement of fertilizer in soil. **Effects:** Seed pieces with brown killed flesh in contact with fertilizer. Roots dead in contact with fertilizer (Fig. 17C). Weak and missing hills. **Control:** Use modern machinery which places fertilizer in two bands at the side and slightly below the seed piece.

Poisoning. Cause: Contact with, or absorption of, a chemical that is too poisonous under the conditions at hand. **Effects:** With salt on tubers, flat on outside, leathery on inside and becoming dark. With too much borax in fertilizer, killing of roots, dying of sprouts, preserving of seed piece from decay, bright yellowing and later burning of

Figure 22. A, hollow heart. Injury to tubers by sodium arsenite herbicide applied to vines: B, lesion at stem end; C, D, and E, slices at stem end, near stem end, and at middle. Vascular discoloration in tuber by a dinitro herbicide applied to vines: F, G, and H, slices from stem end, middle, and eye end portions.

leaves especially at edges, and dwarfing. Sometimes missing hills. Yield reduction. **Control:** Avoid contact of tubers with salty substances. Avoid fertilizers containing excess of borax.

Malnutrition. Cause: Insufficiency of magnesium, potassium (pot-

FIGURE 23. A, magnesium deficiency in leaf. B, terminal leaflets bruised when young by cultivator. C, a leaf sport of a reverting or unstable kind.

ash), or complete fertilizer. **Effects:** With magnesium deficiency, yellow strips in leaflets between the ribs followed by yellowing and dying of the leaves (Fig. 23A). With potassium deficiency, dark green, bronzing, and down-cupping of leaflets followed by their early death and by death of the plants. With fertilizer stoppage, especially at last-planted ends of rows, plants spindling, dwarfed, and light green with consequent confusion about roguing for spindle tuber or leafroll. **Control:** Use properly balanced fertilizer ratio, with magnesium included. Use fertilizer as far in the row as seed pieces are planted.

Bruising. Cause: Rubbing of emerging plant tips by cultivator blades. Impact of tubers on diggers, rocks, soil, baskets, barrels, bins, and graders. **Effects:** Young plants with upper leaves dwarfed and yellow-brown (Fig. 23B), followed by normal growth of branches pushing beyond injured parts. Deep cracks appearing suddenly in tubers during digging. Tubers with comparatively shallow, short to long cracks that occur before storage (Fig. 24, B and C), or with curved, "thumbnail" cracks that become conspicuous after grading of cold-stored crisp tubers followed by some drying out. Offers entrance in tubers to fungus rot (Fig. 24D). **Control:** Handle tubers gently at all times. For deep cracks appearing suddenly during digging, avoid Bliss Triumphs or postpone digging until tubers are more mature or until

Figure 24. Tuber defects: A, growth cracks; B and C, bruising; D, bruise crack with fungus rot started; E and F, blackheart; G, internal brown spot.

soil is warmer. Postpone grading stored tubers until they contain less water, or warm them before grading.

Blackheart. Cause: Insufficient oxygen in the center of the tuber for the maintenance of life. Indirectly, too high temperature or lack of air. **Effects:** Internal blackening, especially at center, of tubers, with flesh still fairly firm unless soft rot has set in (Fig. 24, E, F). Internal cracks. **Control:** Avoid high temperatures, exposing tubers to sun in sunny hot weather in May, or overwarming in transit. Otherwise not important.

INHERENT ABNORMALITIES

Leaf Sports. Cause: Spontaneous changes in composition of the tuber or plant parts that determine heredity. **Effects:** Leaves with abnormal form, surface, and color (Fig. 23C). **Control:** Not important. Rogue out affected plants.

Varietal Leafrolling. Cause: Inherited characteristic of certain varieties. **Effects:** Rolling of lower, middle, or upper leaves, or of combinations of these. Confusion when roguing for leafroll. **Control:** Avoid susceptible varieties, or rogue early before varietal leafrolling develops.

Giant Hills. Cause: Spontaneous changes in composition of the tuber or plant parts that determine heredity. **Effects:** Plants with larger size, late blossoming, and some resistance to fall killing frosts, appearing by tuber units if in tuber-unit plots. Tubers with somewhat "bumpy" outline. **Control:** Rogue out.

DISORDERS WITH CAUSES UNKNOWN

Internal Brown Spot. Effects: Rusty brown spots scattered through the flesh of the tuber (Fig. 24G). **Control:** Not important.

Brown Xylem. Effects: Vascular ring brown in tubers dug before frost from vines with no abnormal appearance.

IDENTIFICATION TABLES

TABLE 1

Effects of Diseases, Insects, and Injuries on Stems and Branches[1]

	Spindling	Erect	Drooping	Oversize	Stunted	Aerial tubers	Cut off	Lesions	Local collapse	Basal decay (foot-rot)	Brown vascular ring	Dark internal streaks	Brown internal spots	Tunnels	Premature death
Late blight								x							x
Early blight								x							
Rhizoctonia					x	x		x		x					
Gray mold								x							
Sclerotinia			x							x					x
Verticillium											x	x			x
Pink rot			x							x					
Blackleg					x	x				x	x	x			x
Ring rot			x												x
Mild mosaic					x										
Crinkle mosaic					x										
Rugose mosaic					x										x
Leafroll	x	x			x										x
Spindle tuber	x	x			x										
Unmottled curly dwarf	x	x			x							x	x		x
Yellow top	x					x					x	x			
Purple top	x		x			x									x
Euschistus bug									x						
Buckthorn aphid															x
Potato aphid															x
Green peach aphid															x
Stalk borers														x	
Cutworms							x								
Wireworms	x				x										
Lightning			x						x	x					x
Hail							x	x							
Poisoning					x										
Malnutrition	x				x										x
Giant hills				x											

[1] For meaning of terms see second section of this bulletin, and for page bearing discussion of a disease, insect, or injury, see alphabetical list on page 3.

TABLE 2

Effects of Diseases, Insects, and Injuries on Leaves

	Lesions	Holes	Rolled	Bunched	Crinkled	Curled	Erect	Stunted	Leaflet stalks swollen	Yellowed	Red or purple	Bronzed	Dark green	Lower surface silvered	Mottled	Streaked	Burned	Sticky honeydew	Wilted	Premature death	Destruction
Late blight	x																			x	x
Early blight	x																			x	
Rhizoctonia			x	x			x			x									x	x	
Gray mold	x																			x	x
Verticillium																			x	x	
Pink rot																			x	x	
Blackleg			x	x			x			x									x	x	
Ring rot										x					x		x		x	x	x
Mild mosaic					x										x					x	
Crinkle mosaic					x										x					x	
Leafrolling mosaic			x		x										x					x	
Rugose mosaic	x				x			x		x					x	x	x			x	x
Latent mosaic															x					x	
Interveinal mosaic															x						
Leafroll			x				x	x		x							x			x	
Spindle tuber			x	x			x						x								
Unmottled curly dwarf				x		x	x	x												x	
Yellow top			x				x			x											
Purple top			x							x	x										
Springtails		x																			
Grasshoppers																					x
Blister beetles																					x
Colorado potato beetle																					x
Potato flea beetle		x															x			x	
Tarnished plant bug			x						x		x								x		
Four-lined plant bug		x																			
Potato leafhopper			x							x	x						x			x	
Buckthorn aphid					x	x									x			x		x	
Potato aphid					x	x									x	x		x		x	
Green peach aphid					x	x									x	x		x		x	
Stalk borers																			x		
Cutworms																			x		
Slugs		x																			
Freezing																x	x		x	x	x
Sunscald														x			x		x		
Tipburn			x							x							x			x	
Lightning																			x	x	
Hail		x																			x
Dry-weather wilting			x																x		
Excess of soil water			x				x			x									x		
Spray injury	x											x					x		x		
Poisoning										x							x				
Malnutrition						x	x	x		x		x	x						x	x	
Bruising				x				x		x											
Leaf sports					x			x		x					x						
Varietal leafrolling			x																		

TABLE 3

Effects of Diseases, Insects, and Injuries on Tubers

	External lesions	Russeting	Black scurf	Sooty skin	Green	Spindle shape	Necklace effect	Swellings, outgrowths	Sponginess	Water-soaked	External cracks	Small holes	External cavities	Rot	Brown vascular ring	Internal streaking	Internal spotting	Discolored internal blotches	Internal cracks	Internal cavities	Tunnels
Late blight	x													x				x			
Early blight	x																				
Scab	x	x						x					x								
Powdery scab	x							x					x								
Rhizoctonia	x	x	x								x	x	x	x							
Gray mold										x				x							
Verticillium															x						
Pink rot										x				x							
Leak										x				x							
Fusarium	x									x				x						x	
Phoma	x													x						x	
Silver scurf	x			x																	
Blackleg and bacterial soft rot										x				x	x	x				x	
Ring rot											x			x					x		
Red-xylem disease	x														x	x				x	
Leafroll																x					
Stem-end browning																x					
Spindle tuber						x					x										
Unmottled curly dwarf						x					x						x				
Yellow top							x									x					
Purple top							x		x												
Potato flea beetle								x				x									x
White grubs													x								
Wireworms												x									x
Midge flies																					x
Fungus gnats													x								
Slugs													x								
Mice and rats													x								
Mites													x								
Millipedes												x									x
Freezing										x					x	x	x	x	x	x	
Mahogany browning																		x	x		
Tuber greening					x																
Lightning														x				x	x	x	
Excess of soil water								x													
Tuber growth cracks											x										
Hollow heart																			x	x	
Witch grass												x									x
Off-type tubers								x													
Spray injury															x					x	
Disinfectant injury	x																				
Poisoning									x									x			
Bruising											x								x		
Black heart																		x	x	x	
Giant hills								x													
Internal brown spot																	x				
Brown xylem														x							

TABLE 4

Effects of Diseases and Injuries on Seed Pieces and Sprouts

	Holes in seed pieces	Tunnels in seed pieces	Cavities in seed pieces	Seed pieces eaten	Seed-piece lesions or rot	Sprout injury	Spindling sprouts	Sprouts slow or absent (missing hills)
Late blight					x			x
Early blight					x			
Rhizoctonia						x		x
Fusarium					x			x
Phoma					x			x
Blackleg and bacterial soft rot					x	x		x
Ring rot					x			x
Leafroll							x	x
Spindle tuber							x	x
Unmottled curly dwarf							x	x
Yellow top							x	x
Purple top							x	x
Wireworms	x	x		x			x	x
Seed-corn and potato-seed maggots	x	x		x	x			x
Millipedes	x	x						
Crows			x	x				x
Freezing					x			x
Mahogany browning					x			x
Excess of soil water					x			x
Disinfectant injury					x			x
Fertilizer burning					x			x
Poisoning					x			x

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